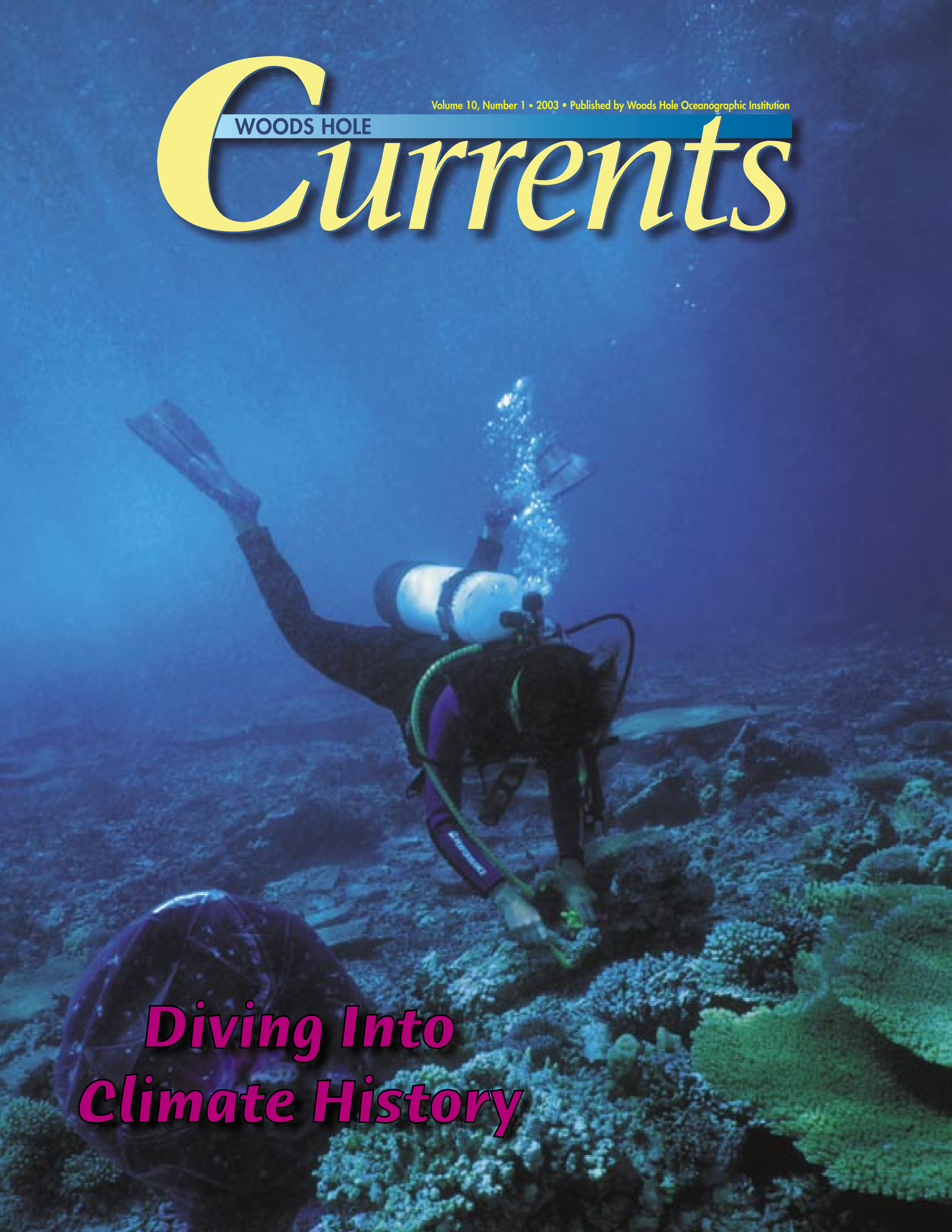

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WOODS HOLE
Currents
Diving Into
Climate History

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WOODS HOLE
Currents

COVER: WHOI Research Associate Anne Cohen stains a live coral on Johnston Atoll in order to determine the time of year when most growth occurs. Such data helps her interpret the climate record she reconstructs from coral skeletons. Photo by Phil Lobel.

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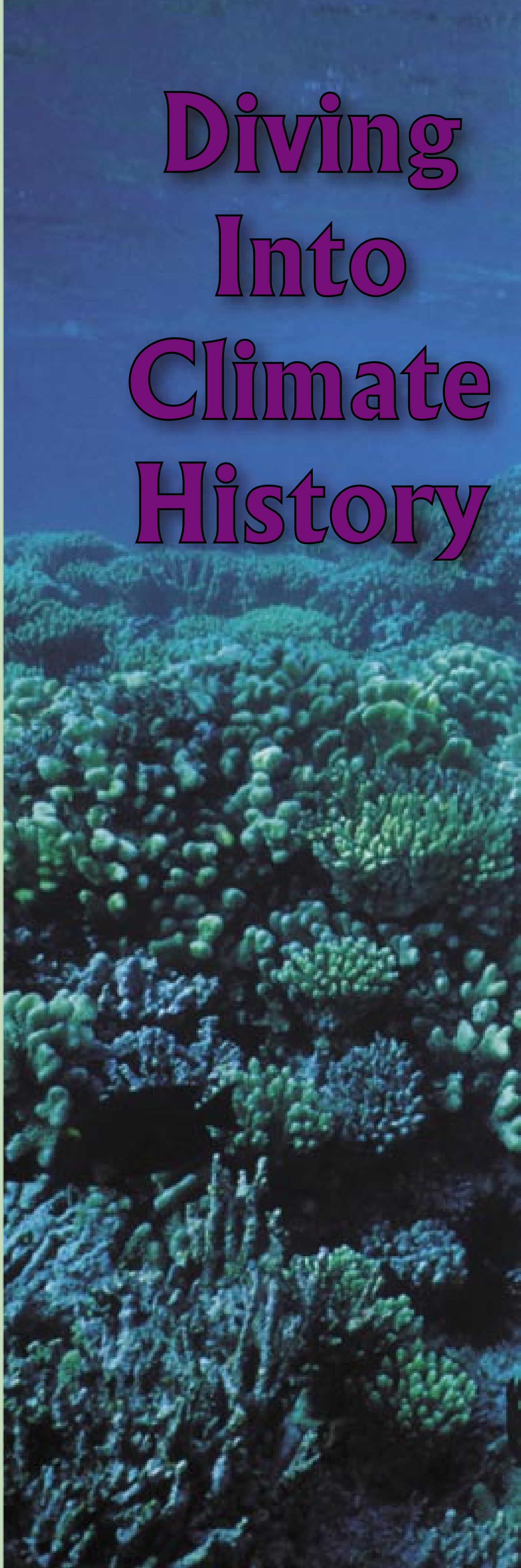
Diving Into Climate History



Phil Lobel

Corals Tell a Story of Past Climate

By Amy E. Nevala

Covered in pink, green, and carrot-orange polyps—and swirling with an assortment of fish just as colorful—coral reefs have a lively exterior that appeals to underwater explorers. WHOI Research Associate Anne Cohen (Geology & Geophysics) is attracted to them for a different reason. Beneath the vibrant surface of every coral lies an archive of climate history.

"Corals look like rocks," Cohen said. "They don't move and they are silent. But they are continuously growing, all the while acting as tape recorders of information we need to track variations in climate."

Those records are written in the coral's calcium carbonate skeleton, and they tell a story of centuries of intense storms and climate flip-flops. Cohen, in her quest to understand major climate events in Earth history, has collected corals from Hawaii, South Africa, Australia, Bermuda, and other far-flung locations.

After plucking coral samples from the sea, Cohen dissects them like a coroner conducting an autopsy. She slices them into cross-sections, then takes X rays and computed tomography scans. She is initially interested in the alternating light and dark bands—a zebra-striped indicator of annual growth that is invisible to the naked eye but clear on an X-ray image (see inset above). Within this banded timeline she can accurately date the coral's growth to the years of the first Moon landing, the invention of the Frisbee, and the introduction of television.

The next step is to couple the age of the coral with chemical analyses. Living coral is sensitive to small variations in ocean temperature, salinity, and light, leading to changes in the chemical composition of the coral skeleton. These signatures of a changing environment are recorded in the coral's growth bands.

Using a mass spectrometer—which determines the abundance of various elements in a sample—Cohen can measure small but telltale changes in the coral's chemistry. A dip in the ratio of strontium to calcium, for example, signals a rise in ocean water temperature. A spike in a certain isotope of oxygen can indicate the occurrence of a typhoon or hurricane. Since Cohen can calculate exactly when the bands were formed, she can determine the calendar years in which those changes took place.

Taking the Temperature of the Ocean

Records of ocean temperature date to about 1900, but the older measurements are sparse and often unreliable. (Prior to 1940, readings were taken by lowering buckets over the side of a ship or dock, and then dipping thermometers in the water-filled buckets). Measuring temperatures became more sophisticated in the 1970s, when computerized monitors were mounted on buoys and docks to record long series of temperatures for months and even years. By the early 1980s, satellites began tracking sea surface temperatures.

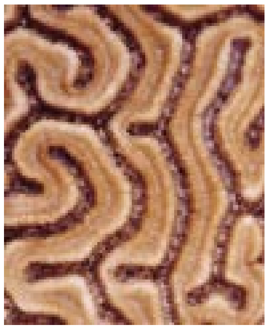
But as Cohen points out, these recent temperature records are too short to tell researchers

Phil Lobel

Research Associate Anne Cohen sizes up a Pavona coral on Johnston Atoll for its potential to provide a climate record.

whether the climate changes in recent decades are unusual or just natural variations. That's where corals prove valuable.

Coral reefs are built slowly by polyps, tiny animals the size of pencil erasers. Living together in vast colonies, polyps draw in calcium and bicarbonate from the ocean to build a hard skeleton that they use for support and protection. Some species continue to grow for many years, forming massive colonies. Over time these may be cemented together by algae, forming the reef structure.



Anne Cohen

Brain coral skeletons are sensitive to changes in ocean conditions.

"Corals are natural climate recorders," said Cohen. "They grow continuously, so there are no gaps in the record. And they grow for a long time, sometimes reaching 1,000 years old."

Corals can provide a useful, uniform tool for reconstructing the chronology of ocean and climate conditions. Take, for example, our understanding of hurricanes. Scientists do not have a sufficiently long record of weather data to accurately determine the probabilities of these catastrophic storms. But hurricanes dump large amounts of rainfall into the oceans. Hurricane rainfall has a unique isotopic composition that is recorded as a distinctive chemical spike in coral skeletons.

"It is like dumping ink into the ocean," Cohen noted. "The signal remains preserved for centuries or even millennia as a record of each hurricane's passage."

Using this sampling method with corals from St. Croix, Cohen found unmistakable evidence for two recent hurricanes, Hurricane Marilyn in 1995 and Hurricane George in 1998. She plans to apply this technique to older corals in order to find undocumented hurricanes from the past, filling in gaps in the weather record and improving our understanding of hurricane frequency. Cohen's work could help improve the calculations of storm risk and boost scientists' understanding of the relationship between hurricane frequency and long-term climatic cycles in the ocean.

Courtesy of Anne Cohen

Anne Cohen (left), Robbie Smith, and Graham Webster secure harnesses to a 1,500-pound brain coral (*Diploria labyrinthiformis*) as they retrieve it from a reef off Bermuda.

© Corbis

As they grow, brain corals assimilate chemical signals from the ocean that reveal changes in the global environment.

Tales of the Reconstruction

Cohen's goal is to build records of past climate variability in order to give context to the patterns we are experiencing today. Climate reconstructions based on proxies such as corals may help determine whether recent climate changes are part of a natural, recurring cycle or if they are unprecedented changes related to human activity. When viewed with this longer perspective, she said, "our perception of climate history might change completely."

Toward this end, Cohen has been examining a 276-year-old, 1,500-pound coral she removed in 2001 from a reef in Bermuda (see page 5). That brain coral may have some interesting things to say about a recurring climate phenomenon known as the North Atlantic Oscillation (NAO).

Like El Niño and La Niña—which periodically rearrange ocean conditions in the Pacific and spread their effects around the globe—the NAO is a periodic climate phenomenon

Continued on page 6

Bringing home
the big guy
with floats and a four-ton winch

She found it on a clear spring afternoon in May 2001. Just by looking, she knew that the massive coral would be perfect for her research.

For ten days, Anne Cohen and two colleagues had donned scuba gear and combed the reefs two miles southeast of Bermuda for the best specimen for reconstructing centuries of climate conditions.

"It had a nice, big, round shape, like a mushroom," said Cohen about the 1,500-pound brain coral she affectionately calls "the big guy." "I estimated that this one was a few hundred years old."

She chose the big coral not only because of its size and likely age, but also because of its condition and location. The venerable coral's days seemed numbered: its stubby stem was eroded, making a collapse imminent. And it was somewhat isolated on the reef, so the researchers could avoid interfering with other corals in the area.

But hauling the massive coral from 50 feet below the surface proved tricky. Cohen and colleagues Robbie Smith and Graham Webster from the Bermuda Biological Station for Research (BBSR) had to hire a local salvage boat with a four-ton winch to haul it in. They labored underwater to secure the coral with harnesses and a float and to score and weaken the stalk with handsaws.

After hours of cutting, the coral broke free and quickly rose to the surface, despite its staggering weight. "It must have taken about 10 seconds," Cohen recalled. "I didn't even capture it on the underwater video camera. It all happened too fast, and I was more concerned with getting out of the way."

Tom Kleindinst

Back on shore, a curious crowd gathered to peer at the rough, maze-like surface of the coral skeleton. A forklift hauled it from the salvage boat to the dock, and a truck carried it to BBSR for packing and shipment. On earlier expeditions, Cohen had her prized specimens held up by US Customs agents. But this time, the coral had a quick and safe passage to Woods Hole.

Tom Kleindinst

Anne Cohen (above) had to find help from rock-cutting experts to slice a section from this 276-year-old coral skeleton. She took her "big guy" to Fletcher Granite Company in Westford, MA, to extract a workable section (below left).

Then her research hit an unexpected wall. When Cohen tried to slice into the skeleton, "the saw just disintegrated," she said. "The coral ate the chainsaw." It took several months to locate someone who could help.

Cohen finally found a quarry that routinely cuts large slabs of marble for buildings, foundations, and statues. Like marble, coral is just another form of limestone or calcium carbonate. Still, the quarry saws had never sunk their teeth into such an unusual rock, so the workers gathered around Cohen's specimen with great interest.

They set up a commercial saw, and after an hour or so, sliced a cross-section of the coral that she could X-ray. The Bermuda brain coral turned out to have been born about seven years before George Washington, dating to 1725.

Today, as Cohen digs into that long climate history book, she is also working with colleagues from Boston University to develop ultrasound-imaging equipment to study corals underwater. In the future, she hopes to collect skeletal data from living corals without having to cut them down and haul them back to the lab.

"We hope to go right in the water with the ultrasound equipment so we don't have to bring the coral out of the water," she says. "We could look at several corals on the same dive, allowing the coral to keep growing and saving us the trouble of having to cut it up."

—Amy E. Nevala

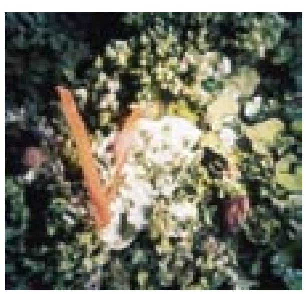
Tom Kleindinst

Associate Scientist Hanumant Singh and Research Associate Anne Cohen examine a section of a brain coral skeleton before inserting it into a computed tomography scanner for three-dimensional imaging. Along with Singh and Boston University colleagues, Cohen is looking for novel ways to "get inside" her coral specimens.

in which the ocean and atmosphere seem to feed back upon each other.

In the "positive" phase of the NAO, a low-pressure atmospheric system lodges near Iceland and a high-pressure system hovers over the Azores. These conditions result in generally milder winters in the eastern US and northern Europe. Ocean temperatures in the northwestern and southeastern parts of the North Atlantic become cooler, but warm up around Bermuda.

In the NAO's "negative" phase, the low- and high-pressure systems move south. Winters in the eastern US and northern Europe become more severe, and storms track farther south, bringing rain to the Mediterranean. Ocean temperatures also change in the North Atlantic, causing temperatures to decrease around Bermuda.



Phil Lobel

Bleached coral on Johnston Atoll reveals a 1996 warming event.

Since the 1970s, the NAO has been "stuck" in a positive phase more intense than any on record. Because the ocean near Bermuda changes in response to NAO, Bermuda brain corals can be used as an NAO recorder. During the positive phase of NAO, when ocean temperatures at Bermuda are higher than normal, the brain corals respond by growing a denser skeleton with a telltale chemical composition. Cohen wants to know: Has the NAO done this sort of thing before, or has the climate crossed some new threshold, perhaps triggered by global warming?

The answer is crucial to predicting future climate changes, which may have wide-ranging economic and environmental ramifications. The recent positive NAO has saved fuel bills and caused fewer weather-related disruptions of transportation in the US and northern Europe. But farther south in the Mediterranean region, it has limited rainfall and hampered water supplies. Some impacts are less obvious. In the Grand Banks, for instance, colder winters are thought to hamper cod reproduction.

In testimony that Cohen delivered to the US House of Representatives in June 2002, she reported that her Bermuda coral research reveals that ocean water temperatures have fluctuated over the past 300 years, but the magnitude and persistence of the warm temperatures since 1980 are clearly an unusual phenomenon. The coral shows that sea temperatures in the 1990s off Bermuda averaged a full degree Celsius higher than in the previous 300 years.

Ironically, the rapid warming of the surface oceans in the past three decades coincides with basin-wide changes in the very reefs that record the climate signals. Higher sea surface temperatures cause corals to lose their colorful polyps—and thus their lives—in a phenomenon known as "bleaching." On some reefs, bleaching has claimed up to 90 percent of the living corals. Higher levels of industrial carbon dioxide in the atmosphere may also acidify the ocean, causing parts of the reef to dissolve and reducing corals' ability to make new skeletons.

"The instrumental record gives us a limited, 50-year perspective on ocean temperatures," said Cohen. "That's simply not long enough to say, with any degree of confidence, whether the recent warming is natural or due to a human influence on climate. It is only through a long-term perspective—such as we get from paleodata like corals—that we can say the mass coral bleaching is unprecedented in the last 1,000 years."

"To learn more about Anne Cohen's work, visit www.whoi.edu/science/GG/people/acohen/